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ECONOMY-WIDE MODELING OF THE AGRICULTURAL SECTOR IN BRAZIL

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Abstract

This paper presents a multisectoral general equilibrium model of the Brazilian economy in which the linkage and interactions between the agricultural and non-agricultural sectors are specified and explored. The paper shows that as the Brazilian economy has moved rapidly through structural transformation in the 1970-1986 period, several important inter and intra-sectoral linkages have evolved between the agricultural sector and the rest of the economy. These sectoral interactions have reduced the relative role of agricultural labor and agricultural GDP in the total labor force and total GDP, respectively. The empirical results in the model corroborate the fact that the large expansion of the Brazilian agricultural exports in the 1970s could only be accomodated at the expense of some land that had previously been used to produce domestic foodcrops.

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1.1 Introduction

The purpose of this paper is to determine how the Brazilian economy, and the agricultural sector has been shaped by changing prices and technologies in the past and will be likely shaped in the future. To accomplish this task we specify a multisectoral general equilibrium model that offers an insight into the past and, in a later section, simulations for the future. This model draws upon the tradition of Samuelson's (1953-54) gross national product function, Gorman's (1968) gross profit function, and McFadden's (1966) restricted profit function. Burges (1974) has developed further the theoretical treatment of Production theory and the derived demand for imports. Kohli (1978) has applied a restricted profit function to determine the supply and demand of imports for the Canadian economy.

Our own treatment expands the previous models by disaggreging the economy into an agricultural and non-agricultural sector. This allows us to determine the interaction between these two sectors in the process of economic growth. Brazilian technology is represented by a restricted profit function with, labor and capital fixed in the short run and the prices of imports, exports, investment and consumption goods exogenous.

For simulation purposes the estimated parameters, along with assumptions regarding the direction and magnitude of future price changes, will allow one to forecast future gross national product, investment, consumption, and the impact of these price changes on the structure of the economy (i.e. on the agricultural and non-agricultural sectors). Thus one can forecast the future share of agricultural product in the total economy and agricultural labor in the total labor force. At the same time the model can forecast total exports, total imports, agricultural exports and imports and non-agricultural exports and imports and the resulting agricultural trade balance in the future. The derived demand for agricultural and non-agricultural labor emerges from this exercise along with the derived demand for capital. A balance of payments function should also be incorporated to equilibrate the current account, but this would take us too far astray from our more limited objectives in this study and is therefore omitted.

1.2 Specification of the Model

The model consists of 10 equations, 10 dependent variables and 9 independent variables. The period covered is from 1970 to 1986. The basic gross national product equation can be expressed as:

$$GDP = I + C + X - M \tag{1}$$

where:

GDP = Gross Domestic Product

I = National Investment

C = National consumption

X = Total Exports

M = Total Imports

From this basic format we introduce a restricted multi-product multi-input indirect profit function, restricted in the sense of assuming producers and consumers maximize profits or utility on the basis of prices of domestic products and of importables and exportables with a given stock of labor and capital each year. Our restricted indirect profit function further disaggregates the economy into an agricultural and non-agricultural sector and is specified as:

$$GDP = f(P_{xa}, P_{xna}, P_{ma}, P_{mna}, P_i, P_{ca}, P_{cna}, K, L_a, L_{na}), \qquad (2)$$

where:

GDP = Gross Domestic Product

P_{xa} = Price Index of Agricultural Exports

P_{xna} = Price Index of Non-Agricultural Exports

P_{ma} = Price Index of Agricultural Imports

P_{mna} = Price Index of Non-Agricultural Imports

P_{ca} = Price Index of Domestic Agricultural Comsumption Goods

P_{cna} = Price Index of Domestic Non-Agricutural Consumption Goods

P_i = Price Index of Investment Goods

K = Stock of Capital

L_a = Agricultural Labor Force

L_{na} = Non-Agricultural Labor Force

Let us assume that Brazilian firms are profit-maximizing firms operating under perfect competition in all commodity and factor markets, and choosing their optimum output mix and import requirements subject to a vector of output and import prices and a fixed endowment of domestic factors of production. We also assume free mobility of factors between firms, and their rental prices are determined by their marginal product.

We assume that the Brazilian aggregate technology is comprised of 3 non-negative domestic primary inputs (fixed in the short-run): Capital(K), Rural Labor (RL), and non-rural labor (NRL). The technology also consists of 7 variable quantities: agricultural imports (MA), non-agricultural imports (MNA), agricultural exports (XA), non-agricultural exports (XNA), investment goods (I), domestic agricultural consumption goods (CA), and domestic non-agricultural consumption goods (CNA).

We denote the fixed input vector by x, the variable quantity vector by y, and the corresponding price vectors by w and p, respectively. The production possibility set T, or transformation set, defines all feasible input and output combinations. We assume that the aggregate technology has constant returns to scale, free disposal, and non-increasing marginal rates of substitution and transformation and that for a given endowment of fixed inputs, the output of variable quantities is finite. Given these conditions of aggregate technology, together with the profit-maximization assumption, the competitive equilibrium at any point in time may be characterized as the solution to the maximization of GNP subject to technology, resource endowments, and a vector of positive output and import prices (Kohli, 1978).

More formally, following Diewert [1973], we may represent the restricted profit (or

GNP) function as follows:

$$\Pi(p;x) = MAX_y(p^{\tau}y: (x;y)\in T, p\gg 0) \tag{3}$$

where Π is a real function (GNP) well defined for all vectors of positive prices p. Diewert derives the following properties for the restricted profit function (3):

(a) linearly homogeneous, monotonically increasing, and concave in fixed-input quantities; and

(b) linearly homogeneous and convex in the prices of the variable quantities and monotonically decreasing or increasing in these prices depending on whether the corresponding quantity is an input or an output.

If the restricted profit function satisfies the above conditions and is, in addition, differentiable with respect to the variable quantity prices at $p^* >> 0$ and $x^* \geq 0$, then Hotelling's (1932) lemma tells us that:

$$\frac{\partial\Pi(p^*;x^*)}{\partial p_i} = y_i(p^*;x^*)$$
$$\textit{with}$$
$$i = MA, MNA, XA, XNA, I, CA, CNA \tag{4}$$

where $y_i(p^*;x^*)$ is the profit maximizing amount of output i given that the firms face the vector of prices prices p^* and have the vector x^* of fixed inputs at its disposal. Similarly, if the restricted profit function (1) is differentiable at p^* and x^* with respect to the components of x, then

$$\frac{\partial \Pi(p^*;x^*)}{\partial x_j} = w_j(p^*;x^*) \quad \text{with} \quad j = K, RL, NRL. \tag{5}$$

where $w_j(p^*;x^*)$ is the inverse demand function of the jth domestic primary input.

Thus, equations (4) and (5) provide us with a system of variable output supply and input demand functions. We need only postulate a functional form for $\Pi(p;x)$ which is consistent with the appropriate regularity conditions for Π and is differentiable with respect to the components of p.

The Hessian of the restricted profit function may be written as:

$$H = \begin{bmatrix} \Pi_{pp} & \Pi_{px} \\ \Pi_{xp} & \Pi_{xx} \end{bmatrix} = \begin{bmatrix} \nabla^2{}_{pp}\Pi & \nabla^2{}_{px}\Pi \\ \nabla^2{}_{xp}\Pi & \nabla^2{}_{xx}\Pi \end{bmatrix} \tag{6}$$

where ∇ is the vector differential operator (gradient). The expression $\nabla^2{}_{pp}\Pi$ is, thus, the vector of second-order differencials of $\Pi(p;x)$ with respect to the components of p. The substitution matrix, Σ, can be defined as

$$\Sigma = \sigma_{mm} = \begin{bmatrix} \Sigma_{pp} & \Sigma_{px} \\ \Sigma_{xp} & \Sigma_{xx} \end{bmatrix} = \begin{bmatrix} \Pi_p^{-1}\Pi_{pp}\Pi_p^{-1} & \Pi_p^{-1}\Pi_{px}\Pi_x^{-1} \\ \Pi_x^{-1}\Pi_{xp}\Pi_p^{-1} & \Pi_x^{-1}\Pi_{xx}\Pi_x^{-1} \end{bmatrix} \tag{7}$$

where $\Pi_p = \mathrm{diag}(\nabla_p\Pi(p;x)$ and $\Pi_x = \mathrm{diag}(\nabla_x\Pi(p;x))$. The symmetry of Σ is implied directly by the symmetry of Hessian (H). In addition, the curvature properties of equation (3) imply that Σ_{pp} is positive semi-definite and that Σ_{xx} is negative semidefinite.

The matrix of variable quantity price elasticity and domestic input quantity elasticities may be defined as follows:

$$E = \begin{bmatrix} E_{pp} & E_{px} \\ E_{xp} & E_{xx} \end{bmatrix} = \begin{bmatrix} \dfrac{\partial \ln Y_i}{\partial \ln P_h} & \dfrac{\partial \ln w_j}{\partial \ln P_h} \\ \dfrac{\partial \ln Y_i}{\partial \ln X_k} & \dfrac{\partial \ln w_j}{\partial \ln X_k} \end{bmatrix} \tag{8}$$

with

$$i,h = MA,MNA,XA,XNA,I,CA,CNA,K,RL,NRL,$$

and

$$j,k = K,RL,NRL.$$

It may be shown (Kohli, 1978) that

$$e_{mi} = \sigma_{mi}\,\frac{p_i y_i}{\Pi} \tag{9}$$

and that

$$e_{mj} = \sigma_{mj} \frac{w_j x_j}{\Pi} \tag{10}$$

with m,i = MA,MNA,XA,XNA,I,CA,CNA,K,RL,NRL and j = K,RL,NRL.

The homogeneity properties of the restricted profit function, $\Pi(p;x)$, imply that rows of E_{pp} and E_{xx} sum to zero while those of E_{px} and E_{xp} sum to unity (Diewert, 1974).

We need only postulate a functional form for $\Pi(p;x)$ which is consistent with the appropriate regularity conditions for Π and is differentiable with respect to the components of p and x. The transcendental logarithmic (translog) function is well suited to our purposes. The translog is a second-order logarithmic Taylor's expansion of the restricted profit function (3) which is sufficiently flexible that it does not restrict the sign of the size of the various substitution elasticities.

The translog variable Hicks-non-neutral profit function Π may be defined as

$$\begin{aligned}\Pi(p;x) = {} & \alpha_0 + \sum_{i=MA}^{CNA} \alpha_i \ln p_i + \frac{1}{2}\sum_{i=MA}^{CNA}\sum_{j=MA}^{CNA} \gamma_{ih} \ln p_i \ln p_h \\ & + \sum_{i=MA}^{CNA}\sum_{j=K}^{NRL} \delta_{ij} \ln p_i x_j + \sum_{j=K}^{NRL} \beta_j \ln x_j + \frac{1}{2}\sum_{j=K}^{NRL}\sum_{z=K}^{NRL} \phi_{jz} \ln x_j \ln x_z + \tau T,\end{aligned} \tag{11}$$

where i,h = MA, MNA, XA, XNA, I, CA, CNA; j,z = K, RL, NRL; and T is time as an index of technological change.

Symmetry of Hessian (H) of equation (6), implied by Young's theorem, requires that

$$\gamma_{ih} = \gamma_{hi} \;\; and \;\; \phi_{jz} = \phi_{zj}. \tag{12}$$

The restricted profit function Π defined by (11) is homogeneous of degree one in p if and only if

$$\sum_{i=MA}^{CNA} \alpha_i = 1; \quad \sum_{i=MA}^{CNA} \delta_{ij} = 0; \quad and \sum_{h=MA}^{CNA} \gamma_{ih} = 0, \tag{13}$$

for j=K,RL,NRL and i=MA,...,CNA.

Similarly, Π(p,x) is homogeneous of degree one in x if and only if

$$\sum_{j=K}^{NRL} \beta_j = 1; \quad \sum_{j=K}^{NRL} \delta_{ij} = 0; \quad and \sum_{z=K}^{NRL} \phi_{jz} = 0, \tag{14}$$

for i=MA,...,CNA, and z,j=K, RL, NRL.

Hotelling's lemma applied to the translog variable profit function defined by (11) yields the following system of variable quantity supply (V_i) and inverse demand (U_i) share functions.

$$\begin{aligned} V_i &= \frac{p_i y_i}{\Pi} = \frac{\partial \ln\Pi}{\partial lnp_i} = \alpha_i + \sum_{h=MA}^{CNA} \gamma_{ih} lnp_h + \sum_{j=k}^{NRL} \delta_{ij} lnx_j \ , \\ U_j &= \frac{w_j x_j}{\Pi} = \frac{\partial \ln\Pi}{\partial lnx_j} = \beta_j \sum_{i=MA}^{CNA} \delta_{ji} lnp_i + \sum_{z=k}^{NRL} \phi_{jz} lnx_z , \end{aligned} \tag{15}$$

where i=MA,...,CNA, j=K,RL,NRL.

Since the shares both, separately must sum to unity, one share equation from the variable quantity system (V_i) and one from the inverse demand share equations (U_j) may be deleted, and estimate the other equations together with equation (11).

The elements of the substitution matrix (Σ) defined in (7) may easily be obtained from the translog functional form (Uzawa, 1962). In fact, the elements of Π_{pp} may be calculated as follows:

$$\sigma_{ih} = \frac{\dfrac{\partial^2\Pi}{\partial p_i \partial p_h} \cdot \Pi}{\dfrac{\partial \Pi}{\partial p_i}\dfrac{\partial \Pi}{\partial p_h}} = \frac{\gamma_{ih} + V_i V_h}{V_i V_h}, \quad \textit{for } i \neq h,$$

and (16)

$$\sigma_{ii} = \frac{\dfrac{\partial^2\Pi}{\partial p_i^2} \cdot \Pi}{\dfrac{\partial \Pi^2}{\partial p_i}} = \frac{\gamma_{ii} + V_i^2 - V_i}{V_i^2}, \quad \textit{for } h=i$$

with i,h = MA,...,NRL.

The elements of Σ_{px} are estimated as

$$\sigma_{ii} = \frac{\dfrac{\partial^2\Pi}{\partial p_i \partial x_j} \cdot \Pi}{\dfrac{\partial \Pi}{\partial p_i}\dfrac{\partial \Pi}{\partial x_j}} = \frac{\delta_{ij} + V_i U_j}{V_i U_j} \tag{17}$$

i = MA, ..., NRL, and j = K,RL,NRL.

Finally, the elements for Σ_{xx} may be estimated

$$\sigma_{jz} = \frac{\phi_{jz} + U_j U_z}{U_j U_z} \ , \ for\ j \neq z,$$

and (18)

$$\sigma_{jj} = \frac{\phi_{jj} + U_j^2 - U_j}{U_j^2}, for\ z=j.$$

where j,z=K,RL,NRL.

1.3 Data Description

The model described in (15) was used to estimate the structure of the Brazilian technology over the period 1970-1986 using yearly data. The primary domestic inputs are capital (K), rural labor (LR) and non-rural labor (NRL). On the variable side, we include agriculture imports (MA) and non-agriculture imports (MNA), exports, both agriculture exports (XA) and non-agriculture exports (XNA), investment goods I, agricultural consumption goods (CA), and non-agricultural consumption goods (CNA). Price and quantity series are required for each good or factor.

The variable output shares were obtained by dividing the total value of each variable output into the total value of GDP at factor cost. The inverse factor demand shares, in turn, were obtained by dividing the respective total factor expenditure by GDP. The total value of agricultural consumption goods was obtained by subtracting the total value of agricultural exports from agricultural GDP. The total value of non-agricultural consumption goods was obtained as the difference between total consumption and agricultural consumption goods. Data limitations did not allow us to separate total investment into agricultural and non-agricultural investement goods. The total value of investment goods was proxied by gross formation of fixed capital.

In the dual system, variable output prices are used rather than physical quantities. The agricultural import price series (PMA) was derived by dividing the total value of agricultural imports (in current Cruzados) into the total volume (in tons) of agricultural imports. The non-agricultural import price series was obtained by first subtracting the value of agricultural imports from the total value of imports and then dividing this result by the difference between the total physical volume of imports and agricultural imports (in tons). A similar procedure was followed to calculate agricultural exports prices (PXA) and non-agricultural export price series (PXNA). The producer price index of agricultural consumption goods (PCA) was proxied by the price index of foodstuffs. The price index of non-agricultural consumption goods was proxied by the price index of consumer durables. Finally, the price index of investment goods (PI) was proxied by the price index of construction materials.

Data on the stock of capital (K) was obtained by assuming that capital depreciation is in the order of 5% of the capital stock during this period. Data on depreciation are available through 1981. From 1982 onwards capital in period t was estimated using the following equation: $K_t = k_{t-1}(1\text{-}d) + I_t$ where d is the rate of depreciation and I is investment.

1.4 Statistical Methods

By assuming that the translog GNP function represents adequately the Brazilian technology and that any deviations of the observed input and output shares from the profit-maximizing shares are due to errors in optimization and are random we specifiy a vector of random disturbances (v, u) = (v_{MA},...v_{CNA}, u_K,...u_{NRL}) such that

$$\sum_{i=MA}^{CNA} v_i = 0, \qquad \sum_{j=K}^{NRL} u_j = 0. \tag{19}$$

The v's and the u's are assumed to be identically distributed normal random vectors with mean vector zero and covariance matrix Σ. After deletion of the equations of consumption of non-agricultural goods and capital for estimation purposes and imposition of the symmetry and homogeneity constraints and using the capital stock as a numeraire for the stock variables the system to be estimated is as follows:

$$\begin{aligned} v_i &= \alpha_i + \sum_{h=MA}^{CA} \gamma_{ih} lnp_i + \sum_{j=RL}^{NRL} \delta_{ij} \ln\left(\frac{x_j}{K}\right) + \gamma_{iT} t + v_i \\ u_j &= \beta_j + \sum_{i=MA}^{CA} \gamma_{ij} lnp_i + \sum_{z=RL}^{NRL} \phi_{jz} \ln\left(\frac{x_j}{K}\right) + \phi_{jT} t + u_j \end{aligned} \tag{20}$$

The system was estimated using the Zellner's [1962] seemingly unrelated procedure. The conventional R^2 and Durbin-Watson statistics, as shown in Table 1, indicate a fairly good fit for non-agricultural imports and exports, agricultural exports, investment goods, agricultural consumption goods, and non-rural labor.

Table 1. R^2 and Durbin-Watson Statistics

Equation	R^2	DW
1 Agricultural Imports	0.45	2.61
2 Non-Agricultural Imports	0.90	2.17
3 Agricultural Exports	0.76	1.71
4 Non-Agricultural Exports	0.90	1.56
5 Investments Goods	0.87	1.62
6 Agricultural Consumption Goods	0.78	2.06
7 Rural Labor	0.40	1.31
8 Non-Rural Labor	0.79	1.03

Source: Model estimation.

The implied estimates of the parameters of the system of equations (i.e., parameters for non-agricultural consumption goods and capital stock share equations) were obtained by using the linear homogeneity restrictions as established in equations (13) and (14). The estimates of the translog GDP function are presented in Table 2. Monotonicity and concavity were checked at each observation based on the parameter estimates in Table 2, and they were satisfied. This set of estimates, called the final specification, is used for the empirical analysis.

Table 2: Estimates of the Translog GDP Function for Brazil, 1970-1986

Parameter	Coefficient	t-statistic	Parameter	coefficient	t-statistic
α_{MA}	0.086	5.10**	γ_{XAXA}	0.052	4.77**
α_{MNA}	0.140	5.76**	γ_{XAXNA}	0.022	2.55**
α_{XA}	-0.023	-0.87	γ_{XAINV}	-0.045	-2.39**
α_{XNA}	-0.057	-2.05**	γ_{XACA}	-0.065	-4.28**
α_{INV}	0.401	6.31**	γ_{XACNA}	0.027	1.25
α_{CA}	0.237	5.18**	γ_{XNAXNA}	0.040	3.53**
α_{CNA}	0.216	2.58**	γ_{XNAINV}	-0.117	-6.23**
β^{o}_{K}	0.60	10.23**	γ_{XNACA}	-0.035	-2.60**
β_{RL}	0.098	1.82*	γ_{XNACNA}	0.072	3.20**
β_{NRL}	0.300	5.81**	γ_{INVINV}	0.158	2.56**
γ_{MAMA}	0.203	0.69	γ_{INVCA}	0.066	2.42**
γ_{MAMNA}	0.015	2.62**	γ_{INVCNA}	-0.012	-1.53
γ_{MAXA}	-0.009	-1.89*	γ_{CACA}	0.180	6.79**
γ_{MAXNA}	0.002	0.36	γ_{CACNA}	-0.12	-3.62**
γ_{MAINV}	0.020	1.85*	γ_{CNACNA}	0.259	2.85**
γ_{MACA}	0.033	4.46**	δ^{o}_{MAK}	-0.007	-2.43**
γ_{MACNA}	-0.064	-4.50**	δ_{MARL}	0.010	1.14
γ_{MNAMNA}	0.053	5.49**	δ_{MANRL}	-0.004	-0.45
γ_{MNAXA}	0.019	2.55**	δ^{o}_{MNA}	-0.007	-1.82*
γ_{MNAXNA}	0.010	1.27	δ_{MNARL}	0.017	1.24
γ_{MNAINV}	0.028	1.59	δ_{MNANRL}	-0.011	-0.85
γ_{MNACA}	-0.055	-4.88**	δ^{o}_{XAK}	0.012	3.23**
γ_{MNACNA}	-0.071	-3.30**	δ_{XARL}	0.037	2.77**

Table 2: (continued)

Parameter	Coefficient	t-Statistic	Parameter	Coefficient	t-statistic
δ_{XANRL}	-0.050	-4.20**	τ_{MA}	-0.013	-2.21**
δ^{o}_{XNAK}	0.012	3.23**	τ_{MNA}	0.001	1.08
δ_{XNARL}	-0.009	-0.57	τ_{XA}	0.002	2.08*
δ_{XNANRL}	-0.002	-0.13	τ_{XNA}	0.001	1.48
δ_{INVK}	-0.035	-3.95**	τ_{INV}	-0.001	-0.35
δ_{INVRL}	-0.054	-1.38	τ_{CA}	-0.001	-0.92
δ_{INVNRL}	0.089	2.56**	τ_{CNA}	-0.001	-0.28
δ^{o}_{CAK}	-0.025	-3.68**	τ^{o}_{K}	-0.003	-1.21
δ_{CARL}	0.032	1.27			
δ_{CANRL}	-0.007	-0.33			
δ_{CNARL}	-0.033	-0.71			
δ_{CNANRL}	-0.017	-0.41			
Φ^{o}_{KRL}	0.58	0.67			
Φ^{o}_{KNRL}	-0.022	-2.60**			
Φ_{RLRL}	-0.043	-1.00			
Φ_{RLNRL}	0.037	0.99			
Φ_{NRLNRL}	-0.015	-0.44			

Double and single asterisks indicate that the coefficient are statistically significant at the 5% and 10% levels respectively. Coefficients with degree marks were computed by imposing the linear homogeneity restrictions.

1.5 Empirical Results

A primary objective was to measure the substitution possibilities between Brazilian agriculture and non-agricultural imports, agricultural and non-agricultural exports, and domestic inputs or outputs during the period 1970-86. We use standard results from neoclassical duality theory to compute these elasticities of substitution from the data using estimated parameters. The elasticities of substitution between Brazilian products and inputs were estimated using equations (16), (17), and (18). We focus our attention in the interaction between the Brazilian agricultural sector with the rest of the economy. Thus, we present in Tables (3) to (6) the substitution elasticities of agricultural exports, agricultural consumption goods, agricultural imports, and rural labor with the economy as a whole.

Agricultural Exports: Table 3 presents the partial elasticity of agricultural exports with respect to other components of the GDP model. Elasticity coefficients (estimated for each year of the 1970-86 period) have been averaged for selected periods in the past 16 years. Column 6 sets forth the average for the entire period in each table. It is this column that will be used in discussing our findings in each table. The most important results from Table 3 is the strong negative elasticity recorded between the output of agricultural exports (XA) and the price of domestic market agricultural consumption goods (CA) in line 6. Domestic market agricultural consumption goods includes both foodstuffs and livestock and dairy products. The negative elasticity implies that agricultural exports and domestic agricultural consumption goods are substitutes. If the price of domestic agricultural goods rises say by one percent, the output of agricultural exports will decline by 1.25 percent (line

Table 3

Selected Price and Quantity Elasticities for Agricultural Export Goods Derived from the Multisectoral Aggregate Gross Domestic Product Model for Brazil For Selected Periods 1970-86.

ELASTICITY TERMS	AGRICULTURAL EXPORT (XA) ELASTICITIES					
	1970-73	1974-79	1980-83	1984-86	1980-86	1970-86
	(1)	(2)	(3)	(4)	(5)	(6)
1. $E_{XA\ PMA}$	0.36	0.41	0.40	0.32	0.36	0.38
2. $E_{XA\ PMNA}$	0.60	0.48	0.31	0.24	0.28	0.38
3. $E_{XA\ PXA}$	0.06	0.16	0.13	-0.02	0.06	0.10
4. $E_{XA\ PXNA}$	0.44	0.49	0.50	0.44	0.47	0.47
5. $E_{XA\ PINV}$	-0.66	-0.73	-0.75	-0.63	-0.69	-0.70
6. $E_{XA\ PCA}$	-1.20	-1.32	-1.32	-1.10	-1.21	-1.25
7. $E_{XA\ PCNA}$	1.20	1.21	1.25	1.15	1.20	1.20
8. $E_{XA\ RL}$	0.80	0.85	0.83	0.71	0.77	0.81
9. $E_{XA\ NRL}$	-0.72	-0.81	-0.72	-0.58	-0.65	-0.73
10. $E_{XA\ K}$	0.92	0.95	0.89	0.88	0.88	0.92

Notes:
XA = Value of Agricultural Export Goods
PMA = Priced Agricultural Import Goods
PMNA = Priced Non-Agricultural Import Goods
PXA = Priced Agricultural Export Goods
PXNA = Priced Non-Agricultural Export Goods
PINV = Priced Investment Good
PCA = Priced Agricultural Consumption Goods
PCNA = Priced Non-Agricultural Consumption Goods
RL = Quantity of Agricultural Labor
NRL = Quantity of Non-Agricultural Labor
K = Stock of Capital

6, column 6). As we shall see shortly, the obverse is also true, as the price of agricultural exports rises, the output of domestic agricultural consumption goods declines.

This empirical result in the model corroborates the export vs. domestic market debate that has characterized much of the professional literature on Brazilian agriculture in the past decade. The resource base in Brazil was such that it was not possible to accomodate the large expansion of agricultural exports in the 1970's, except through land expansive mechanization. This came at the expense of some land that had previously been used for producing domestic foodcrops. The marked shift of land area out of domestic and into export crops (i.e., soybeans) in the South in the 1970's highlights this fact.

Other revealing results can be seen in lines 8 and 10 where a positively elastic (complementary) relationship is documented between the stock of agricultural labor (line 8, column 6) and the total national stock of capital (line 10, column 6) and the output of agricultural exports. Moreover, these elasticities (0.81 for the stock of capital and 0.92 for the stock of capital) are fairly important in size. Again this supports conventional wisdom, namely, that agricultural exports are positively stimulated by increases in rural labor and capital (or conversely, negatively impacted by declines in labor and capital). Both of these factors are important to the output performance of this sector. Given the importance of capital intensive techniques for agricultural export activities, it is not surprising that a strong elasticity of almost unity (one) is recorded for this input.

In addition to the stock of capital, the price of investment goods (PINV) affects agricultural exports (line 5, column 6). Here, as expected, the negative elasticity implies that if the price of investment goods declines by 1.0 percent, agricultural exports, will increase by 0.70 percent. Given the importance of selected capital goods (agricultural machinery, tractors, etc.) for agricultural exports, it is to be expected that the price of these inputs would be negatively associated with agricultural export output.

The high positive elasticity recorded for the relationship between non-agricultural consumption goods and agricultural exports is less instructive and less meaningful in this model (line 7, column 6). This grows out of the fact that while domestic agricultural consumption goods could be appropriately specified (i.e. by subtracting exports from the value of total agricultural output), it was not possible to remove the continuing influence of agricultural exports in a series for non-agricultural consumption goods by subtracting agricultural consumption goods (which is the value of domestic agricultural consumption goods) from total national consumption. Thus with this continuing role of agricultural exports imbedded in the non-agricultural consumption goods data set, we shall focus on the other variables for which the specifications are more clear-cut for the remainder of this section.

A final result of some significance is the own-price elasticity for agricultural exports (line 3, column 6). This own-price elasticity has the right sign (+) indicating that if prices of agricultural exports increase by one percent, the supply of agricultural exports will increase by one-tenth of one percent. But the own-price stimulus is weaker than the impact from other sectors of the economy. This weaker response, though positive, could very likely be derived from the various trade controls and export taxes levied on agricultural products over this period dampening what otherwise would have been a stronger impact of export prices on export output. Also it is important to remember that aggregate elasticities would always be less than those characteristic of individual products. At the same time it is not surprising to note the relatively important impact that other sectors and factors in the economy have on the output of agricultural exports given the large and complex nature of the Brazilian economy.

Domestic Agricultural Activity: In this light it is instructive to look at the elasticity coefficients for domestic market agricultural consumption goods (CA) in Table 4. Here the own-price elasticity of CA is relatively high and, as expected, positive (line 6, column 6). The high level of this elasticity (2.4) highlights the strong impact of local prices on local agricultural output. A rise of domestic prices of one percent will generate a 2.4 percent increase in the supply of domestic agricultural output. Among other things this underscores the relevance of determining a proper pricing policy for this sector.

The fairly strong negative elasticity of domestic market output to the price of agricultural exports (-1.16 in line 3) merely reflects what was discussed earlier, namely, the strong tradeoff that exists between agricultural export and domestic market activity in these data. This also holds for the negative elasticity for non-agricultural export activity.

Table 4

Selected Price and Quantity Elasticities for Agricultural Consumption Goods Derived from the Multisectoral Aggregate Gross Domestic Product Model for Brazil for Selected Periods 1970-86.

ELASTICITY TERMS	DOMESTIC AGRICULTURAL CONSUMPTION GOODS (CA) ELASTICITIES					
	1970-73	1974-79	1980-83	1984-86	1980-86	1970-86
	(1)	(2)	(3)	(4)	(5)	(6)
1. $E_{CA\ PMA}$	0.58	0.52	0.77	0.72	0.75	0.61
2. $E_{CA\ PMNA}$	-0.88	-0.77	-1.18	-1.13	-1.17	-0.93
3. $E_{CA\ PXA}$	-1.09	-0.97	-1.47	-1.36	-1.43	-1.16
4. $E_{CA\ PXNA}$	-0.59	-0.52	-0.76	-0.70	-0.74	-0.61
5. $E_{CA\ PINV}$	1.38	1.28	1.74	1.61	1.69	1.44
6. $E_{CA\ PCA}$	2.21	1.87	3.23	2.96	3.13	2.40
7. $E_{CA\ PCNA}$	-1.37	-1.6	-2.04	-1.88	-1.99	-1.49
8. $E_{CA\ RL}$	0.64	0.56	0.78	0.74	0.77	0.65
9. $E_{CA\ NRL}$	0.11	0.14	0.15	0.14	0.15	0.10
10. $E_{CA\ K}$	0.25	0.31	0.06	0.12	0.09	0.21

Notes:
CA = Agricultural Consumption Goods
PMA = Price of Agricultural Import Goods
PMNA = Price of Non-Agricultural Import Goods
PXA = Price of Agricultural Exports
PXNA = Price of Non-Agricultural Exports
PINV = Price of Investment Goods
PCA = Price of Agricultural Consumption Goods
PCNA = Price of Non-Agricultural Consumption Goods
RL = Quantity of Agricultural Labor
NRL = Quantity of Non-Agricultural Labor
K = Stock of Capital

The positive elasticity with the stock of labor (.65) is more important than for the stock of capital(.21) in column 6 of Table 4 which confirms our understanding that labor is a relatively more important factor of production than capital to increase the supply of domestic agricultural consumption goods. Furthermore, these findings confirm that the elasticity with the stock of capital is far more important for agricultural export output (.92 from Table 3, line 10 column 6) than for domestic agricultural output (.21 from Table 4 line 10 column 6).

The high positive elasticity for investment goods (1.44) in column 6 of Table 4 reflects among other things the positive impact of the rising price of agricultural investment in breeding cattle, swine, etc., on domestic agricultural feedstock activity. The only positive elasticity recorded for the tradeable sector for CA activity is for the price of agricultural imports in line one. This relfects the competitive relationship between agricultural imports (which consists of food and feedstock as well as agricultural capital goods) and domestic agricultural output. If the price of agricultural imports rises by one percent then the supply of domestic agricultural output also increases (in this case by 0.61 percent), since demand in this case shifts from the tradeable to the non-tradeable (i.e., domestic) sector.

Agricultural Imports: Table 5 shifts out focus to agricultural import goods (i.e., food and agricultural inputs such as feedstock, fertilizers, agricultural chemicals, machinery and tractors). Here the elasticity coefficients refer to the impact of price changes of selected GDP components on the demand for agricultural imports (MA). The own-price elasticity is negative (-0.68) as we would expect. If the price of agricultural imports rises one percent, the demand falls 0.68 percent.

Notice in column 6 of Table that the major positive elasticities are associated with non-agricultural imports (line 2), investment goods (line 5) and domestic agricultural consumption goods (line 6). As prices rise for non-agricultural imports, there is a decline in non-agricultural imports which in turn increases the demand for agricultural imports. As the price of agricultural investment goods rises within total investment, there would be a substantial increase for agricultural imports (largely feedstock and agricultural imputs) to service this increased demand. And finally as the price of domestic agricultural consumption goods rises (either foodstuff or feedstock components), there would be an increase in agricultural imports (again both food or feedstocks) to service this demand. In these latter two cases the impact of the positive elasticities have been substantial (2.24 for a rise in the price of investment goods, and 3.31 for domestic agricultural consumption goods).

Finally, there is a remarkably high negative elasticity (-5.33) for non-agricultural consumption goods (CNA) and agricultural imports (line 7). While this variable (CNA) is biased in the sense of still containing the influence of agricultural exports (as we explained earlier), there is still a logical reason above and beyond this bias to explain the strength ofthis negative elasticity with agricultural imports. As the price of non-agricultural consumption goods rises (largely manufactured goods), this increases the output of these same goods. Since manufacturing output is very import-intensive, drawing heavily on oil, intermediate and capital good imports, a rise in the demand for non-agricultural imports will necessarily reduce the foreign exchange available for agricultural imports and reduce these imports.

TABLE 5
Selected Price and Quantity Elasticities for Agricultural Import Goods Derived from the Multisectoral Aggregate Gross Domestic Product Model for Brazil for Selected Periods 1970-86.

ELASTICITY TERMS	AGRICULTURAL IMPORT GOODS (MA) ELASTICITIES					
	1970-73	1974-79	1980-83	1984-86	1980-86	1970-86
	(1)	(2)	(3)	(4)	(5)	(6)
1. $E_{MA\ PMA}$	-0.68	-0.73	-0.68	-0.54	-0.64	-0.68
2. $E_{MA\ PMNA}$	1.60	1.36	1.61	2.24	1.78	1.60
3. $E_{MA\ PXA}$	-0.88	-0.73	-0.88	-1.23	-0.98	-0.88
4. $E_{MA\ PXNA}$	0.22	0.19	0.25	0.34	-0.27	0.23
5. $E_{MA\ PINV}$	2.25	1.93	2.23	3.07	2.44	2.24
6. $E_{MA\ PCA}$	3.32	2.78	3.30	4.70	3.70	3.31
7. $E_{MA\ PCNA}$	-5.33	-4.33	-5.31	-7.93	-5.99	-5.33
8. $E_{MA\ RL}$	1.11	-0.92	1.08	1.52	1.20	1.09
9. $E_{MA\ NRL}$	-0.13	-0.06	-0.05	-0.23	-0.11	-0.10
10. $E_{MA\ K}$	0.02	0.14	-0.02	-0.28	-0.08	0.01

Notes:
MA = Agricultural Import Goods
PMA = Price of Agricultural Import Goods
PMNA = Price of Non-Agricultural Import Goods
PXA = Price of Agricultural Exports
PXNA = Price of Non-Agricultural Exports
PINV = Price of Total Investment
PCA = Price of Agricultural Consumption Goods
PCNA = Price of Non-Agricultural Consumption Goods
RL = Quantity of Agricultural Labor
NRL = Quantity of Non-Agricultural Labor
K = Stock of Capital

Rural Wages: The final Table (Table 6) sets for the the elasticity profile between rural (i.e., agricultural) wages and the price changes for the other sectors and factors of production in the economy. As we observe in column 6 of Table 6, the own-price elasticity is significantly negative (-1.55) as expected (line 8). As the stock of labor (RL) declines, the price of labor rises (and vice-versa). The wage returns to labor are also intimately linked to capital. As the stock of capital (K) rises (or falls) in line 10, rural wages rise (or fall). This positive elasticity is expected since the marginal product of labor (i.e., the wage) depends upong the stock of capital with which it works. This finding of a complementary relationship is corroborated by the basic data in Brazil which shows a rising trend of real rural wages throughout the 1970's along with increases in capital stock in agriculture, and a comparable fall for both during the recession years.

At the same time there are important positive complementary elasticities recorded for rural wages with respect to agricultural exports in line 3 and domestic agricultural consumption goods in line 6. As increase (or decrease) in prices in these two sectors clearlycreates an increase (or decrease) in supply and thus in the demand for rural labor and rural wages rise accordingly. The negative elasticity with respect to the price of investment goodsis also logical. For example a decline in the price of agricultural capital goods will increase their use and generate an increased demand for rural labor and a rise in rural wages for labor employed with this capital.

Table 6
Selected Price and Quantity Elasticities for Rural Wages Derived from the Multisectoral Aggregate Gross Domestic Product Model for Brazil for Selected Periods 1970-86.

ELASTICITY TERMS	RURAL WAGE (RW) ELASTICITIES					
	1970-73 (1)	1974-79 (2)	1980-83 (3)	1984-86 (4)	1980-86 (5)	1970-86 (6)
1. $E_{RW\ PMA}$	0.12	0.16	0.19	0.18	0.18	0.16
2. $E_{RW\ PMNA}$	0.27	0.34	0.39	0.35	0.37	0.33
3. $E_{RW\ PXA}$	0.46	0.59	0.69	0.67	0.68	0.58
4. $E_{RW\ PXNA}$	-0.08	-0.10	-0.11	-0.09	-0.10	-0.09
5. $E_{RW\ PINV}$	-0.38	-0.55	-0.73	-0.73	-0.73	-0.56
6. $E_{RW\ PCA}$	0.40	0.52	0.58	0.57	0.57	0.50
7. $E_{RW\ PCNA}$	0.38	0.24	0.19	0.19	0.19	0.27
8. $E_{RW\ RL}$	-1.38	-1.58	-1.69	-1.66	-1.67	-1.55
9. $E_{RW\ NRL}$	0.04	0.05	0.09	0.07	0.08	0.06
10. $E_{RW\ K}$	0.74	0.78	0.73	0.75	0.74	0.75

Notes:
RW = Rural Wages Index
PMA = Price of Agricultural Import Goods
PMNA = Price of Non-Agricultural Import Goods
PXA = Price of Agricultural Exports
PXNA = Price of Non-Agricultural Exports
PINV = Price of Total Investment
PCA = Price of Agricultural Consumption Goods
PCNA = Price of Non-Agricultural Consumption Goods
RL = Quantity of Agricultural Labor
NRL = Quantity of Non-Agricultural Labor
K = Stock of Capital
P = Aggregate Price Index

1.6 Concluding Remarks

In conclusion, the findings of the general equilibrium GDP model are consistently strong and convincing in tracing out the impacts of the structural (i.e., the inter and intra-sectoral) linkages shaping the performance of the agricultural sector in the past 16 years. Specifying the model in a flexible translog form conveniently created partial elasticities that allows us to determine the relative causal impact of various components of the GDP model on the output of agricultural exports, imports, domestic consumption and agricultural wages.

As the Brazilian economy has moved rapidly through structural transformation in the post-war period, several inter-sectoral and intra-sectoral interactions have been operating, reducing the relative role of agricultural labor and agricultural GDP in the total labor force and total GDP. The cross elasticities betwen the agricultural and non-agricultural sector are strong and important. The trade-off between agricultural exports and domestic agricultural output is equally strong and important. Also the strong influence of the capital stock and the price of investment goods on agricultural exports, imports, domestic consumption and rural labor is substantial. In the latter case the price and the changing stock of capital clearly played a role in substituting for labor (reducing the role of agricultural labor in the labor force) but raising the marginal product of labor (its wage) for that labor that remained in the sector.

Also the relatively greater role of capital in promoting agricultural exports as compared to domestic agricultural output is clear. The own-price elasticities in contrast to the cross price elasticities are generally lower for agricultural tradeables than for agricultural non-tradeables. Finally, the own price elasticity of agricultural labor was quite high, further highlighting the highly price sensitive nature in the use of this factor of production in agriculture.

The rate of technical change in Brazilian economy was captured by the Hicks-non-neutral technological change coefficients (τ) on the time variable in each share equation. The coefficient for agricultural imports indicates that the index of productivity of agricultural imports declined in 1.13% each year. It is statistically significant at 5% level. The coefficient for agricultural exports, on the contrary, is positive indicating that productivity of agricultural exports increased each year. The coefficient for agricultural consumption goods is negative, so its productivity has declined each year.

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